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Characterisation of a Line-Tunable He-Xe Laser Operating at 2.026 and 3.894 µm

K. J. Grant and R. J. Rossiter

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Kenneth J. Grant and Robert J. Rossiter

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ABSTRACT

A neutral rare gas laser has been built, and used to produce continuous wave output in the near- and mid-infra-red regions. The He-Xe mixture was excited by a hollow cathode discharge, and line-tunability was achieved by use of a diffraction grating as the rear optic. Two of these lines, viz. 2.026 and 3.894 μm, are of particular interest due to their location in the 2 and 4 μm atmospheric windows, respectively. A parametric study was conducted to determine the optimum working regimes (total pressure, partial pressure ratio, current, output coupler transmission, and grating).

This General Document is a paper presented at the Australian Conference on Optics, Lasers and Spectroscopy (ACOLS), held at the University of Melbourne in December, 1993.

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EXECUTIVE SUMMARY

A neutral rare gas laser has been built, and used to produce continuous wave output in the near- and mid-infra-red regions. The He-Xe mixture was excited by a hollow cathode discharge, and line-tunability was achieved by use of a diffraction grating as the rear optic. Two of these lines, viz. 2.026 and 3.894 μm, are of particular interest due to their location in the 2 and 4 μm atmospheric windows, respectively. A parametric study was conducted to determine the optimum working regimes (total pressure, partial pressure ratio, current, output coupler transmission, and grating).

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Ken joined the Electronic Warfare Division in 1988, after completing his Ph.D in laser spectroscopy at the University of New South Wales. His research in EWD includes the development of infra-red lasers for electronic countermeasure applications, signature measurement, and assessment of laser warning receivers and missile approach warning systems. He is currently in the Communications Division, working on optical techniques in signal processing.

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Robert joined the Electronic Warfare Division in 1987, after several years working as an Instrumentation Engineer in industry. He has an Honours Degree in Physics from the University of Queensland. Since joining EWD he has been involved in the development and use of infra-red lasers for electronic countermeasures applications, the assessment of laser warning receivers and missile approach warning systems and measurement of signatures.

Contents

1. Introduction

A line-tunable He-Xe laser has been built, and used to produce continuous wave output in the near- and mid-infra-red regions. Use of a rear mirror results in simultaneous lasing on several lines [1,2]. In the present work, tunability was achieved by use of a diffraction grating as the rear optic.

Two of the observed lines, viz. 2.026 μm ($5d[3/2]_1$ - $6p[3/2]_1$) and 3.894 μm ($5d[1/2]_0$ - $6p[1/2]_1$), are of particular interest due to their low atmospheric absorption coefficients of 0.21 and 0.14 km^{-1}, respectively. The high transmission at these wavelengths makes them suitable for a range of applications, including communications and metrology. A parametric study was conducted to determine the optimum working regimes (total pressure, partial pressure ratio, current, output coupler transmission, and grating).

2. Laser system

Two gratings were available for use as the rear optic, viz. 300 line/mm (2 μm blaze) and 150 line/mm (4 μm blaze). There was also the choice of three output couplers. Their transmissions as functions of wavelength are shown in Figure 1. The output couplers were 25 mm ZnSe concave mirrors with a 15 m curvature on the inside face. The laser cavity is 1.6 m long, which means that the configuration is a stable resonator. The external surfaces were anti-reflection coated. The water- cooled discharge tube was 1.3 m long, with a nominal internal diameter of 6.6 mm.

The gases (He > 99.999%, Xe > 99.995% purity) were delivered to the tube via a moisture trap and 7 μm particulate filters. Fine control was maintained over the pressure of the gases by calibrated needle valves. The total pressure was measured by a capacitance pressure gauge. Excitation of the gas mixture was by a hollow cathode discharge, and ballast resistors of 5 kW and 7.5 kW were in series with the power supply at the cathode and anode ends of the tube, respectively.

3. Experimental layout

The experimental layout is shown schematically in Figure 2. An XT-compatible computer controlled the current and recorded the power. The lasing wavelength was confirmed by inserting a monochromator (not shown in Fig. 2) between the laser and the power meter. Figure 3 is a photograph of the laser system.

4. He-Xe 2.026 μm line

The output power of this line is shown as a function of discharge conditions in Figures 4a and b. The other parameters, which were found to be optimum, were: 300 line/mm grating, output coupler A, and total pressure 11 torr. Figure 4a shows that there is a threshold current which is required for lasing. The higher the He:Xe ratio, the greater the required current. Above the threshold, power increases monotonically with current up to the maximum available of 110 mA. In Figure 4b, power is plotted versus He:Xe partial pressure ratio for a range of currents. For each current there is an optimum He:Xe ratio. The higher the current, the larger the optimum He:Xe ratio i.e. the leaner the mixture is in Xe. The maximum power of 5.2 mW is obtained at 110 mA and He:Xe = 80:1.

The 2.026 μm line also lases with the 150 line/mm grating (in second order) and with output coupler C, but with lower power. In addition, the power decreases as the total pressure is increased. (11 torr is the lowest pressure that will sustain a stable discharge.)

5. He-Xe 3.894 μm line

Figure 5a shows the power as a function of the current at several He:Xe ratios. For He:Xe ratios greater than about 70:1, power increases monotonically with current. However, mixtures which are more Xe-rich, i.e. He:Xe < 70:1, have an optimum current, above which the power falls. In contrast to the 2.026 μm line, lasing would take place at 10 mA for all He:Xe ratios. Power is shown as an explicit function of partial pressure ratio, for a range of currents, in Fig. 5b. The optimum ratio is a function of the current, such that the higher the current, the leaner the optimum mixture is in Xe. Maximum power of 6.3 mW is produced at 110 mA with He:Xe = 110:1.

The power of the 3.894 μm line is at its maximum with the 150 line/mm grating, output coupler B, and 11 torr pressure. It also lases with output coupler C, and with the 300 line/mm grating, but at lower power.

(The 3.995 μm line ($5d[1/2]_0$ - $6p[1/2]_1$), which has previously been observed to lase in pulsed mode [3], would not lase cw.)

6. Acknowledgements

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7. References

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2. Grant, K.J. "Design aspects and parametric characterisation of a neutral rare gas laser" ERL-0703-GD (1993)

3. Grant, K.J., Brunker, S.A. and Rossiter, R.J. "Investigation at two wavelengths of a modulated He-Xe rare gas laser" ERL-0508-RN (1990)

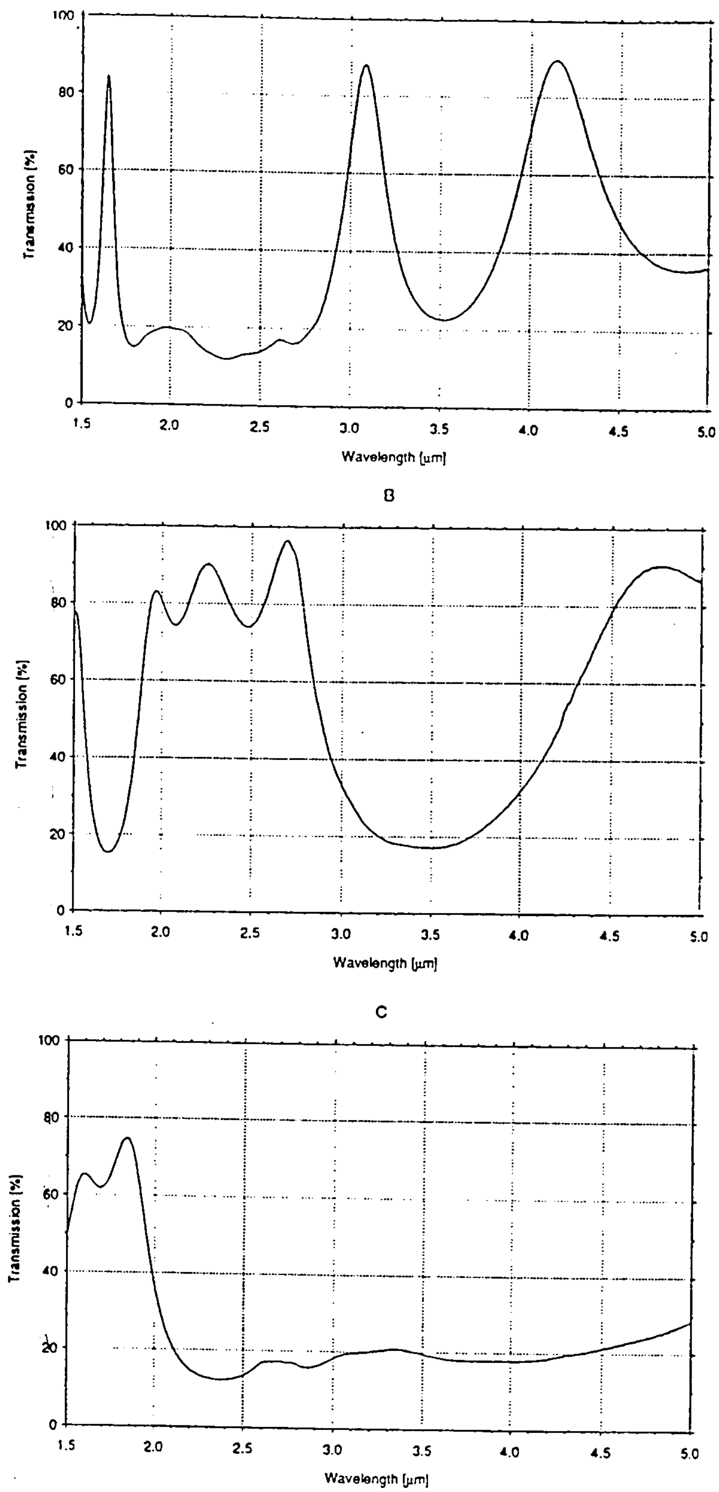

Figure 1: Transmission of the output couplers versus wavelength

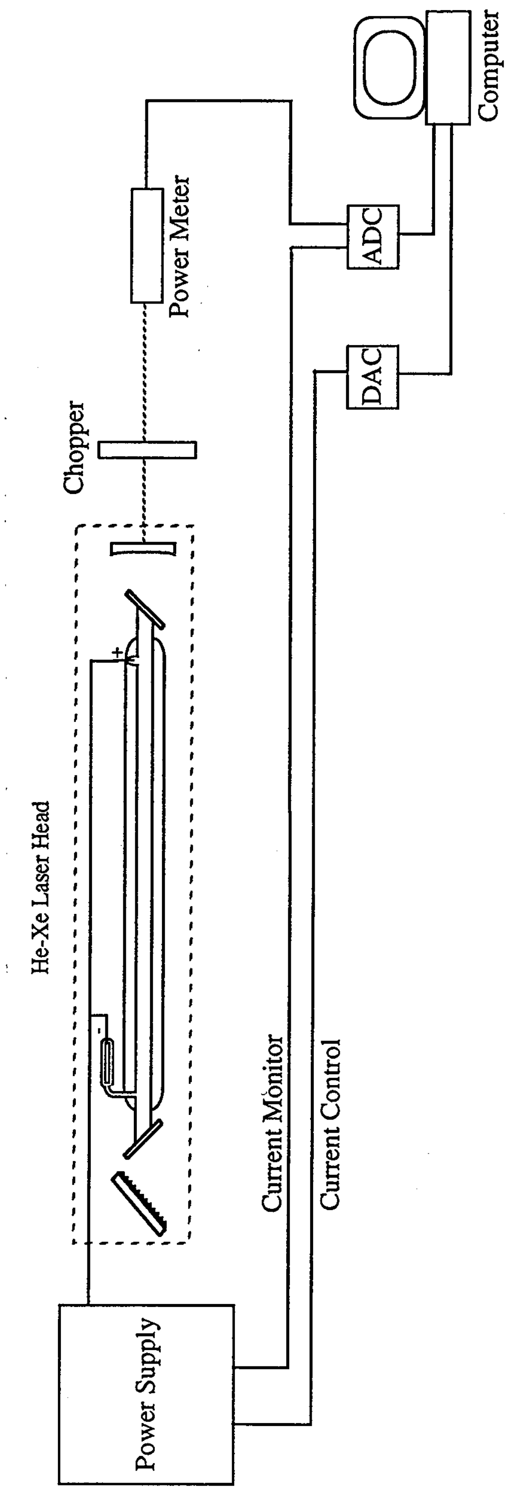

Figure 2 *Experimental layout*

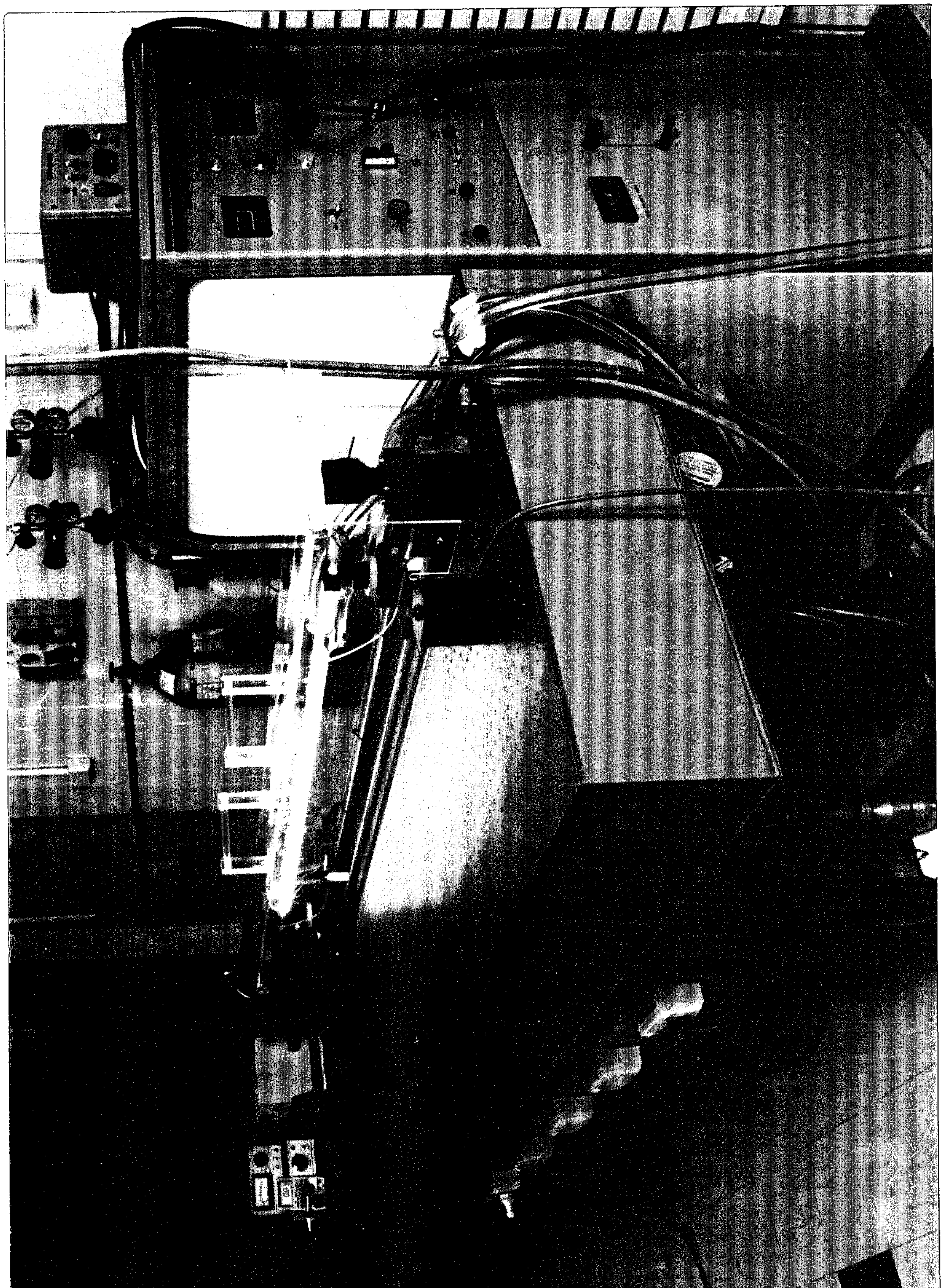

Figure 3: Laser system

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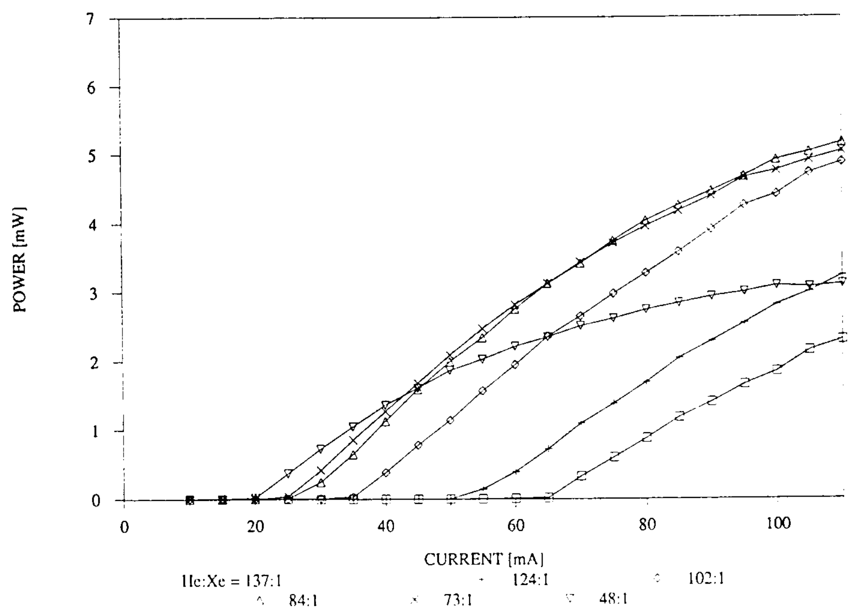
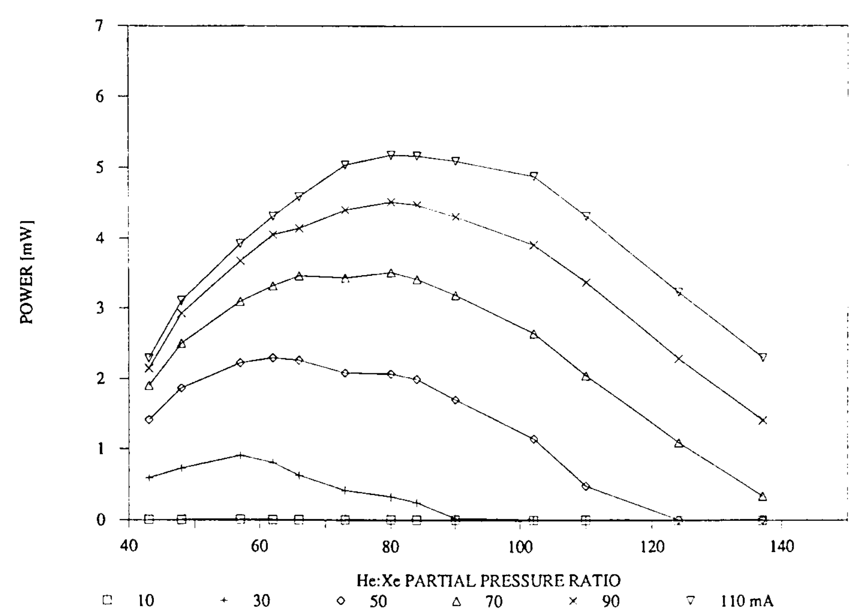
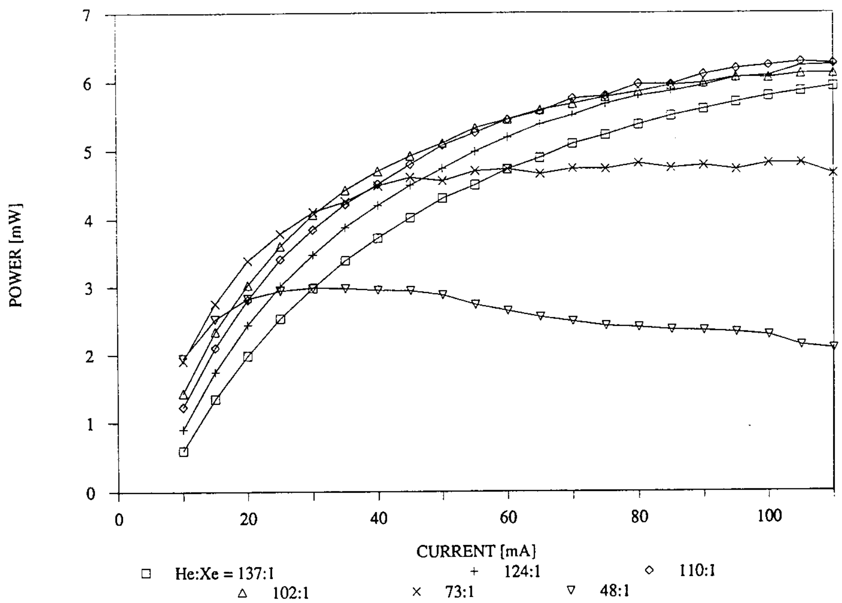


(a)

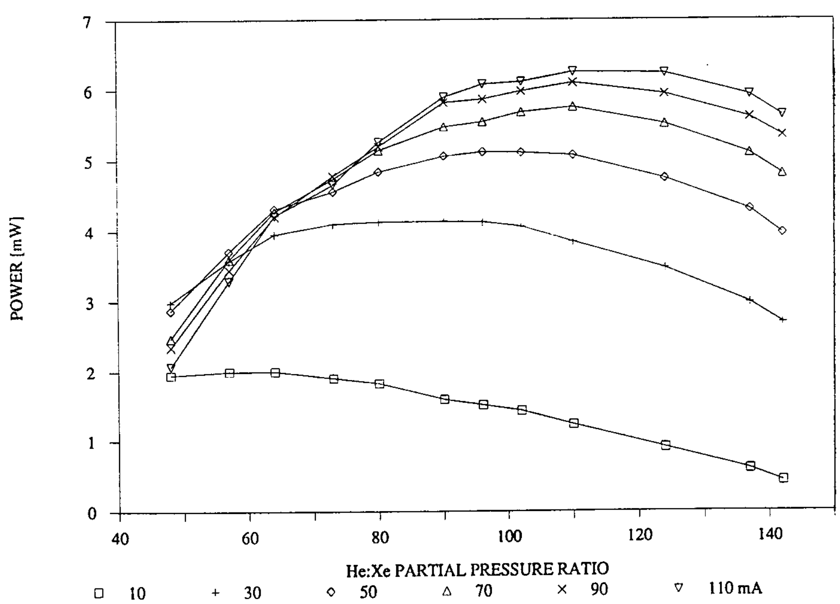


(b)

Figure 4: Power of He-Xe 2.026 μm line versus a) current, and b) He:Xe ratio



(a)



(b)

Figure 5: Power of He-Xe 3.894 μm line versus a) current, and b) He:Xe ratio

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